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C25F6

THERMAL PERFORMANCE AND DELIVERY CAPABILITY OF AN ELECTRIC WATER HEATER WITH A NON-PRESSURIZED PLASTIC TANK

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A prototype electric water heater with a non-pressurized plastic tank was tested for thermal performance and delivery capability according to the applicable Canadian standard. The heater satisfied the standard's requirements with an especially low standby loss. The reliability of its pumping system needs improvement.

INTRODUCTION

Residential water heating constitutes a major electrical load to Ontario Hydro and a capital expense because of the significant numbers of installed rental units. Design improvements to tank durability and energy efficiency are sought and evaluated as they develop. One such development is a well insulated, electric water heater with a non-pressurized plastic tank.

There are two attractive features of this water heater: plastic tank construction and pressureless operation.

Some regions of the province have much more corrosive domestic water supplies than others. Water heaters constructed from steel can fail frequently due to corrosion. Plastic tanks may last longer in these harsh water areas, saving time-consuming, costly repairs.

Pressureless operation allows the tank to be designed with a more modest structure. This means that larger volume tanks can be built to smaller physical dimensions. They weigh less, and are easier handled in narrow, awkward cellar accesses. As well, larger volume tanks are being investigated for potential use for load shifting and for reducing customer bills with time-of-use energy rates. The absence of pressure-stress on the tank may lead to an increased life span.

The prototype water heater, described in the next section, was tested in accordance with selected clauses of the CSA Standard C191-M1983/1/.

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TANK DESIGN

Repressurization of the hot water for supply to the faucets is accomplished through the use of a novel Pressure Transfer Module (PTM) which is installed inside the tank. No additional electrical pumping energy is required.

The PTM is a pump powered by the line pressure of the incoming cold water. It is comprised of two pistoned chambers linked mechanically, with associated intake and discharge porting. One chamber intakes cold supply water under pressure. This pressure is exerted on the cold side piston and is transferred by linkage to the opposing piston and chamber. This latter chamber contains hot water from the top of the tank. As long as hot water faucets are closed, this mechanism is static but is providing water supply pressure. When a water draw occurs, pistons and valves begin moving in a cyclic motion providing water displacement. Cold water discharged from the previous chamber is directed via a dip tube to the bottom of the tank, preserving stratification. Tank water level is controlled by the PTM.

The tank is constructed with a polypropylene inner shell and a polyethylene outer shell sandwiching 3 inches of polyurethane foam thermal insulation. The tank shape is semi-cylindrical, flattened on two opposing sides. This narrow profile facilitates easy handling through doorways, etc. A snap-on plastic panel allows access to thermostats and electrical connections.

The tank weighs 25 kilograms (dry) and has a nominal storage capacity of 300 litres. The exterior dimensions of the tank are: 119 cm (H) x 68 cm (W) x 82 cm (D).

TEST METHODS AND INSTRUMENTATION

The following tests described in the CSA Standard C191, Series M1983, were performed to establish the thermal performance and delivery capability of this water heater.

Tank Capacity	Clause 5.4
Energy Efficiency	5.6
Delivery	5.11
Diffusion	5.7
Upper Zone	5.10
Heating Element Input	5.5
Thermostat	5.8.1

All tests were performed at Ontario Hydro's water heater test facility.

No modifications to the standard CSA tests were required because of the special construction of the tank.

Tank temperatures, water flow rates, and electrical energy consumption were recorded, verified and stored in machine readable form for analysis.

TEST RESULTS AND DISCUSSION

Tank Capacity

Tank capacity was measured using a nutating disk flow meter. Total volume at line pressure was 299 litres. The CSA standard stipulates that the tank volume must be within +7%, -0% of its stated capacity. For this reason, this tank can officially be labelled a 280 to 299 L model.

Energy Efficiency

The results of the energy efficiency (standby loss) test are graphically illustrated in Figure 1. The thermostat cycle period, in excess of twenty hours, is long compared with other tanks. This long cycle period is possible because of the extensive thermal insulation around the tank.

The standby loss was 77 W. This compares very well with the standard requirement of 115 W for nominal size water heaters of 201-300 L and it is relatively low for a tank with this capacity. *(Note: The proposed ban on CFC blowing agents could cause future insulation 'R' values to decrease, thus increasing the standby loss somewhat.)*

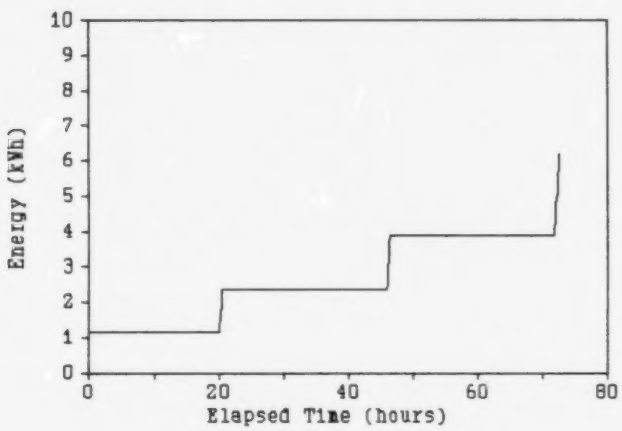

Figure 1
Energy Efficiency (Standby Loss) Test

Delivery Test

The hot water delivery requirements were met by this tank. The tank has sufficient storage and installed power to maintain the standard delivery temperature when subjected to 16 daily withdrawals totalling 635 litres. A water heater is deemed to have failed a delivery schedule if the temperature difference between the average outlet temperature minus the inlet temperature drops below 44 °C, except that one draw may drop to 39 °C above the inlet temperature.

Figure 2 is a differential graph which shows that the average outlet temperature minus the inlet temperature never dropped below the 39 °C limit *(the minimum temperature difference was 42°C).*

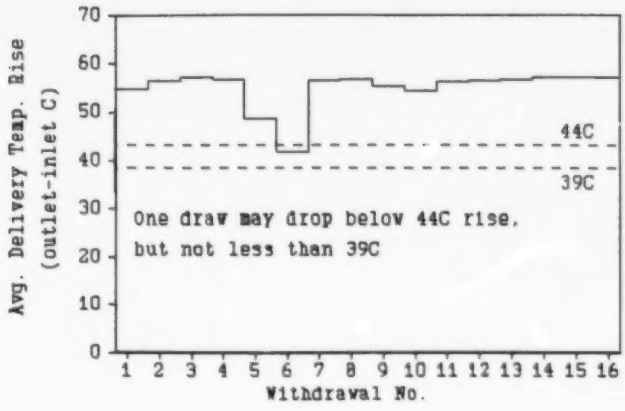

Figure 2
Delivery Test

During the delivery test, both the energy supplied as hot water and electricity were recorded. The energy output as hot water divided by the energy in as electricity is the operating efficiency of the tank. Over a twenty-four hour test period, 39.3 kWh of electricity were consumed and 37.5 kWh were delivered as hot water. This yields an operating efficiency of 95%. Figures 3A and 3B show the electricity consumption and the energy delivered as hot water over the test period.

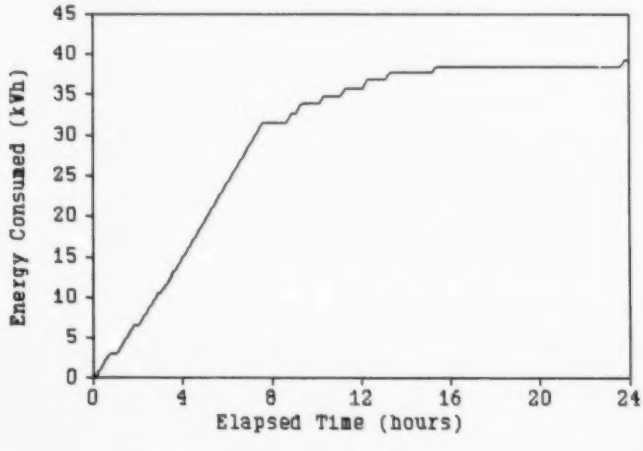

Figure 3A
Electricity Consumption

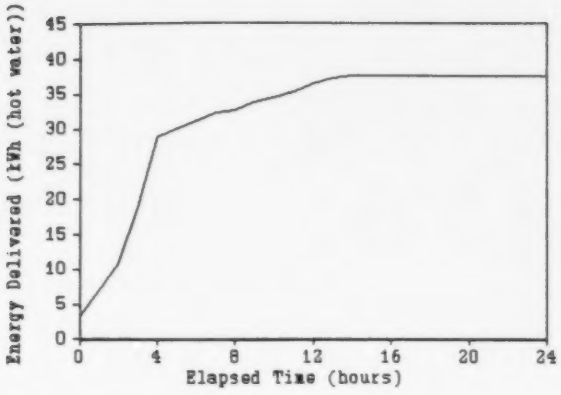

Figure 3B
Energy Supplied as Hot Water

Diffusion Test

The diffusion test indicated that the percentage of the total tank volume of delivered hot water before the outlet temperature dropped 17 °C was 90% (270 litres). This is the minimum requirement for this test. Figure 4 shows the outlet temperature versus volume of water flowed during the diffusion test.

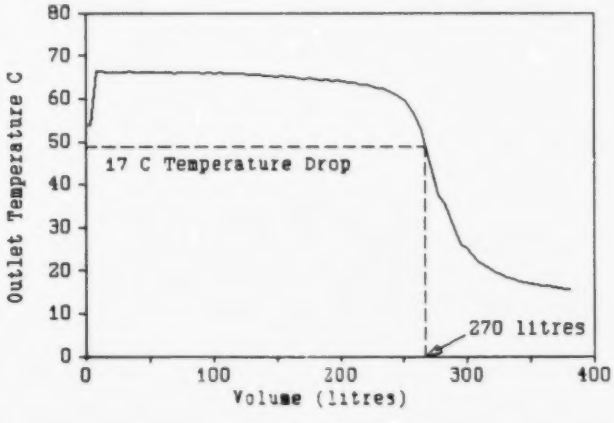

Figure 4
Diffusion Test

Upper Zone Test

The upper zone test determines the volume of water heated by the top element. The test is conducted on a cold tank with the lower thermostat disabled. The upper element is operated until cycling off thermostatically. The thermostat was set for a 56 °C rise above the inlet water temperature of 10 °C. Water was drawn off at 18 L/min., until the outlet water temperature dropped 17 °C below set-point.

Figure 5 shows the outlet temperature versus volume of water drawn.

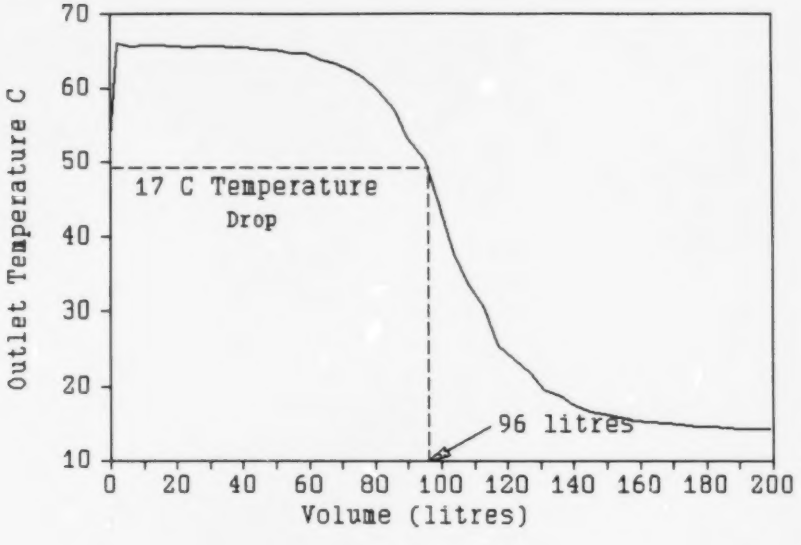

Figure 5
Upper Zone Test

The tank provided 96 litres of hot water up to the point before its discharge temperature declined 17 °C. This meets the CSA requirement of 25% of the tank volume; in this case 75 L.

Heater Element Input Test

Heater element input was measured for each element. The measured power inputs to the upper and lower elements were 4670 and 4580 Watts respectively. Both elements complied with the CSA requirement of 4500 W ± 5%.

Thermostat Tests

Thermostat tests were performed on the upper and lower thermostats of the tank. The test consisted of measuring the top-of-tank temperature after three or more cut-outs of the thermostats. Each thermostat was tested independently of the other at the 50, 60, and 77°C settings. Table 1 summarizes the results.

TABLE 1

Upper Thermostat Setting	Actual Top-of-Tank Temperature
50 °C	50.0 °C
60 °C	62.4 °C
77 °C	81.0 °C
Lower Thermostat Setting	**Actual Top-of-Tank Temperature**
50 °C	50.8 °C
60 °C	59.7 °C
77 °C	78.9 °C

In order to comply with the CSA requirement, the top-of-tank temperature must be within 3 °C of the thermostat setting. The lower thermostat passed the test, but the upper thermostat failed at the 77 °C setting (by 1 °C).

Equipment Reliability

Although not part of the CSA standard tests, degradation of the equipment was observed over the test period.

During the tests, especially the high temperature ones, a 1 cm swelling of the exterior casing of the tank was noticed. The swelling subsided when the tank was emptied.

At the end of testing, a failure of the tank's circulation pumping system occurred, causing the tank to overfill. A possible flood was avoided because of the manufacturer's inclusion of an overflow protection float switch which cut off the flow of water.

CONCLUSIONS AND RECOMMENDATIONS

1. The "pressureless" water heater complied with the requirements of the selected clauses of the CSA Standard C191-M1983 except for the following:

   Clause 5.8: The upper thermostat is not accurate enough in the higher range of temperatures.

2. The recovery and delivery capabilities of the water heater are satisfactory. The standby energy loss is much lower than required.

3. The pumping system needs improvement for reliable long-term applications.

4. The tank swelling needs further investigation to ensure that it does not indicate a structural problem.

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Reference

1. CSA C191 Series-M1983, CSA Standard on Performance of Electrical Storage Tank Water Heaters - Performance of Electric Products. Canadian Standards Association, 1983.